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Technical Memorandum

UTILIZING CAEDOS TO PROGRAM 2-AXIS CONTOURING ON NUMERICALLY CONTROLLED POINT TO POINT MILLING MACHINES

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This Memorandum describes the manner in which a procedure (and software) for utilizing a numerically controlled point to point milling machine as a 2-axis contour milling machine was developed, demonstrated and implemented on CAEDOS.

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ABSTRACT

This Memorandum describes the manner in which a procedure (and software) for utilizing a numerically controlled point to point milling machine as a 2-axis contour milling machine was developed, demonstrated and implemented on CAEDOS.

ADMINISTRATIVE INFORMATION

This document was prepared under Division Overhead Job Order 641Y00. The author of this Memorandum is located at the New London Laboratory, Naval Underwater Systems Center, New London, CT 06320.

INTRODUCTION

A point to point milling and drilling machine will move its table from one point to precisely another point, however, unless this is a straight X or Y axis move, it will not travel a straight line to get there. By contrast, a contour milling machine will move its table (and tool chuck, for 3-5 axis contouring) from one point to precisely another point, while moving in exactly a straight line. This requires more complicated algorithms in the machine controller's software, as well as precise coordination between the machine axis' movements, both of which are lacking in a point to point machine.

The only numerically controlled machines Code 422 has are Pratt & Whitney point to point milling/drilling machines, built in 1968. In order to accommodate jobs that encompass milling anything other than either straight X or Y axis moves (i.e., angled or curved contours), the following effort was undertaken.

USE OF CAEDOS

During the course of a CAEDOS design task, some geometry was developed that heretofore was impossible for the Shop to machine because of the complex curves involved. See Diagram 1.1. It was determined that this would make a good test case to demonstrate the CAEDOS numerically controlled milling capabilities, so the following first steps were tried:

1) Used #INS MPROFILE command, specifying in and out tolerances of 5 thousandths.

2) Used #MACHINE command to generate the Center Line file.

3) All the post processors provided on Code 412 CAEDOS were tried, knowing the Tape-O-Matic required a tab sequential format. Only BGBG04 was tab sequential, however, it does not output a file suitable in other respects for the Tape-O-Matic. Additionally, it requires:

Fixed Block Format

No Decimal Points

3 Place Precision

Mr. Clint Hill, the Computer Aided Engineering Support Office's NC representative at China Lake, was contacted and it was found out that there were no post processors in hand to do what was required.

Subsequently, a VARPRO2 program was written by Code 412 to process the post-processed text file into a usable form. The paper tape was then punched and run. By inserting a scribe in the chuck of the machine, the toolpath in Diagram 1.2 was obtained. This is a graphic demonstration of what occurs when profiling tapes are run on a point to point machine.

A finer definition of our coordinates was required. We then proceeded again thru the sequence of commands #INS MPROFILE, #MACHINE, the post-processor BGBG04 and the VARPRO2 post-post-processor with the exception that the finish tolerances both in and out were defined in the #INS MPROFILE command to 1 ten thousandth instead of 5 thousandths.

When the tape was run, the toolpath shown in Diagram 1.3 was obtained. This was a little better, however, Code 412 specifications were not met. Notice that where the geometry approaches a straight line, (see Diagram 1.4), the profile software inputs fewer coordinates, and the point-to-point machine deviates from the true course.

Regardless of apparent straightness, it was decided to evenly distribute more toolpath coordinates over the entire toolpath.

AN ALTERNATE APPROACH

Using the #CONSTRUCT OFFSET command, new geometry was generated offset from the original geometry by the radius of the cutter to be used. This new offset geometry represented the toolpath that was required for the Tape-O-Matic.

The offset geometry was measured and the length divided by the distance wanted between toolpath coordinates, (in this case, 3 hundredths of an inch). This provided the number of toolpath coordinates needed.

Using the #GENERATE POINT ON command with the NUMBER modifier, points on the offset toolpath geometry were generated. These points represent the toolpath coordinates.

Now, either #INS MPOINT or #INS MABS, followed by #MACHINE and a post, could be used to generate a toolpath. Then it could be run thru the VARPRO2 post-post-processor to convert it to Tape-O-Matic format.

Another option is to write an NC processor to extract the coordinate information needed directly from the toolpath points that were just created, and output it in Tape-O-Matic format all in one step. Utilizing this option, our final toolpath was created, see Diagram 1.5.

It is to be noted that the finish can be made finer by making the distance between coordinates smaller, or by using a larger diameter tool.

One problem in developing the NC processor program (see Attachment (1), was that there were no characters on any keyboards that put an ASCII tab into the output file. The control I tab in the editor inputs several spaces into the text file, but this is not adequate. An ASCII tab causes text following it to jump over to a pre-defined column location in the editor. Every different kind of keyboard Code 412 had was researched trying to find a key that would input an ASCII tab. Finally, an existing paper tape was read thru the tape reader, edited to isolate just one ASCII tab, then fed that thru the VARPRO2 command CVASCII and returned the equivalent CHR (137). (This can be seen on Attachment (1).)

CONCLUSIONS

As a result of the above software modifications, 2-axis contouring can now be done. It is to be noted, however, that the Tape-O-Matic was never intended nor designed for contouring. This use results in extra wear on the machine controllers and very long paper tapes. Therefore, the solution addressed in the text of this Technical Memorandum should only be termed an interim fix.

RECOMMENDATIONS

It is recommended that 3-5 axis contouring machines be purchased in accordance with Code 40's 5-Year Plan. Acquisition of these types of machines would enhance Code 42's manufacturing capabilities in the multiple axis contouring area.

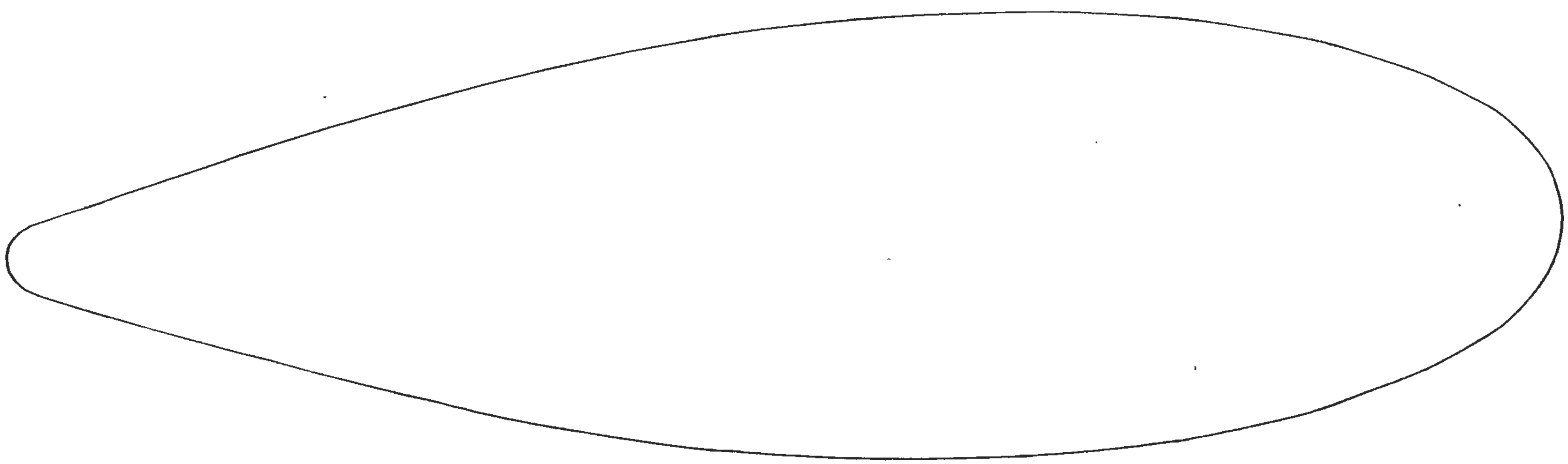
If a contouring machine is chosen that is compatible with the CAEDOS system, additional savings can be achieved in three ways:

1) Because existing CAEDOS equipment can be used to generate the toolpath, an original capital investment to purchase a computer to drive the contouring machine is unnecessary.

2) CAEDOS geometry created to support design documentation can also be used to directly generate the toolpath, thus accomplishing a double productivity gain and avoiding the need to reenter the data in another system. (Past practice has been for the machinist to manually reproduce data from drawings in NC tape form using the flexowriter.)

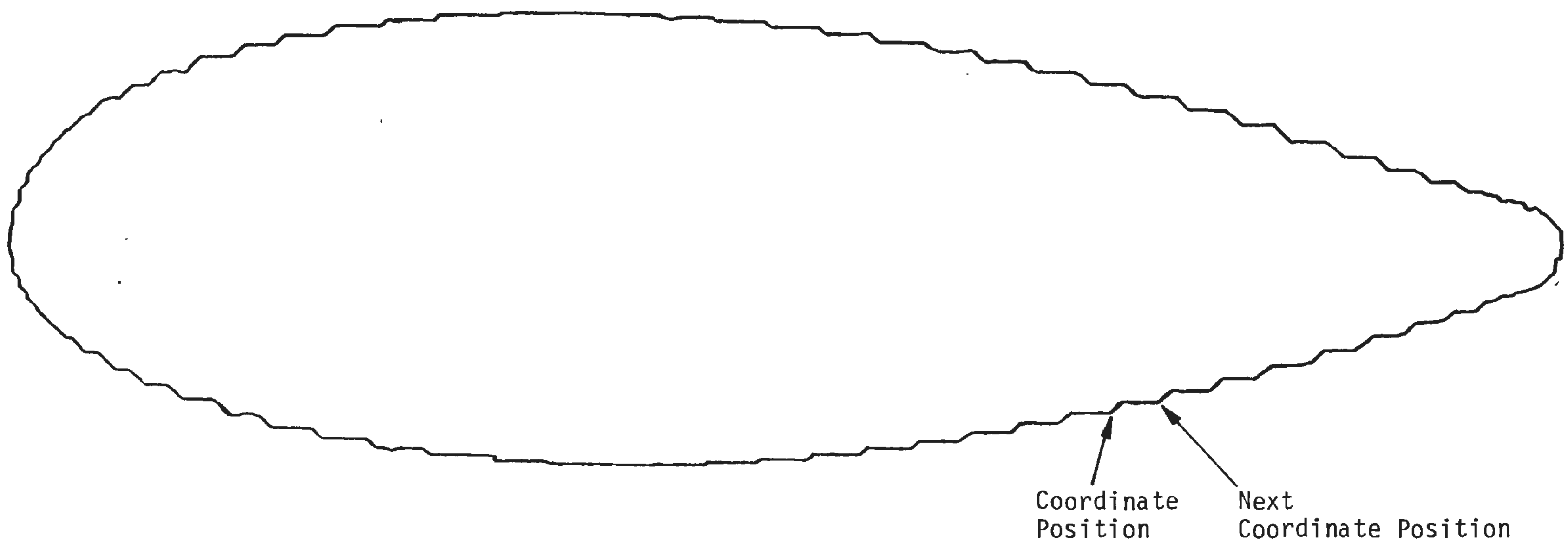
3) Utilizing CAEDOS to directly generate NC toolpaths makes possible a much faster turnaround between need and product, and represents a labor cost savings.

Another benefit of owning a contouring machine is that it is more versatile than a point-to-point machine. While point-to-point machines are very limited in the degree to which they can be forced to do contouring, contouring machines can readily and easily be utilized for point-to-point functions such as drilling or tapping. Thus, when both Tape-O-Matics are busy (which is not uncommon) the contouring machine could be used to fill in the gap instead of doing the job manually.



CAEDOS GENERATED GEOMETRY

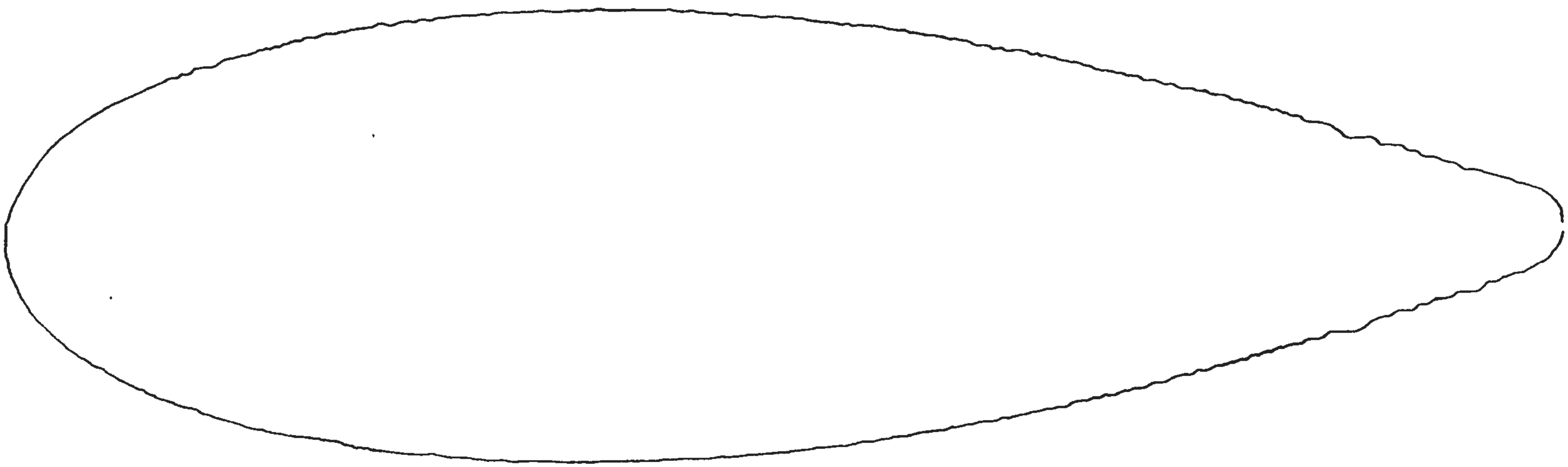
DIAGRAM 1.1



TOOLPATH PRODUCED BY #INS MPROFILE

IN/OUT TOLERANCE .005

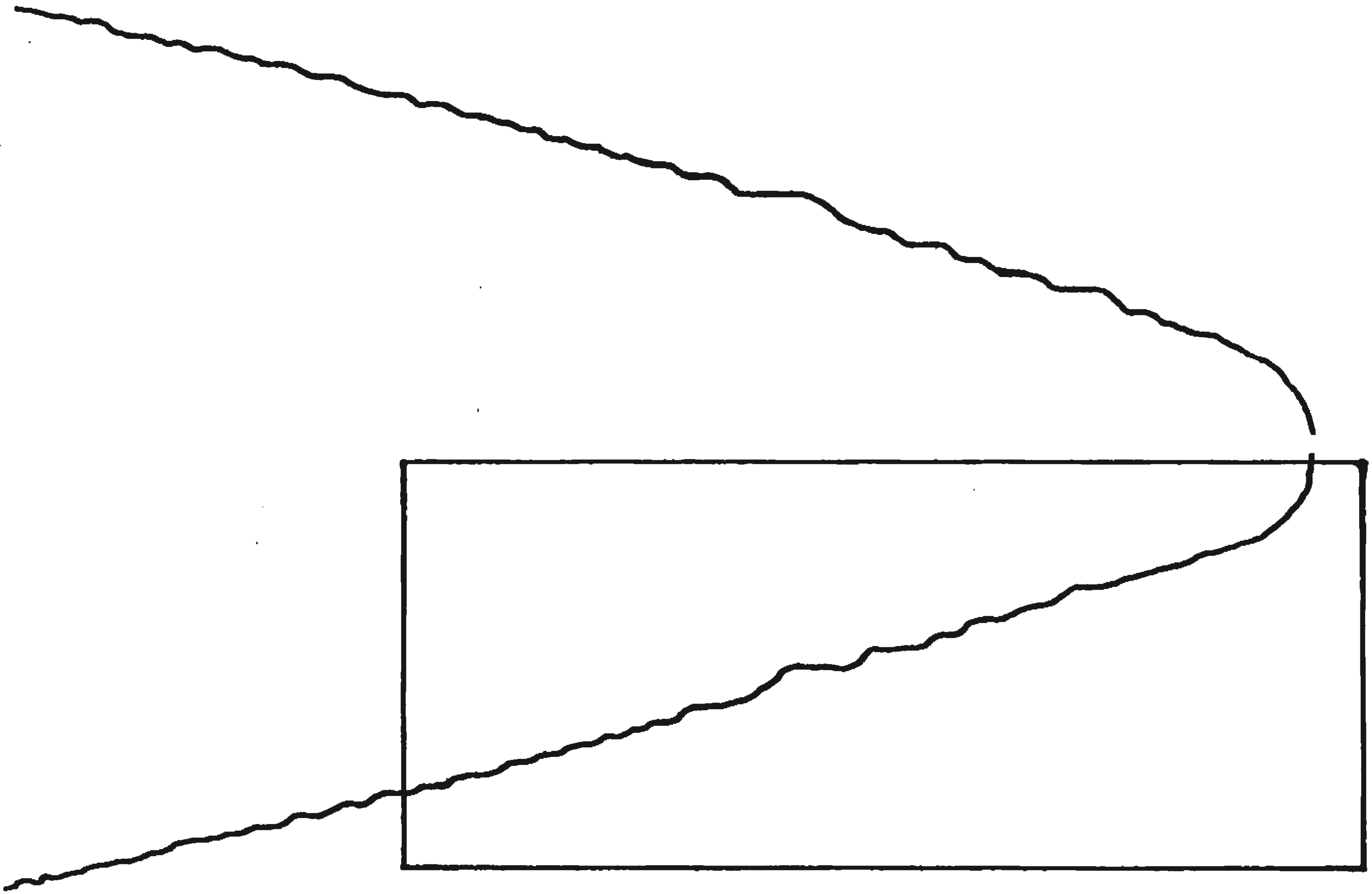
DIAGRAM 1.2



TOOLPATH PRODUCED BY #INS MPROFILE

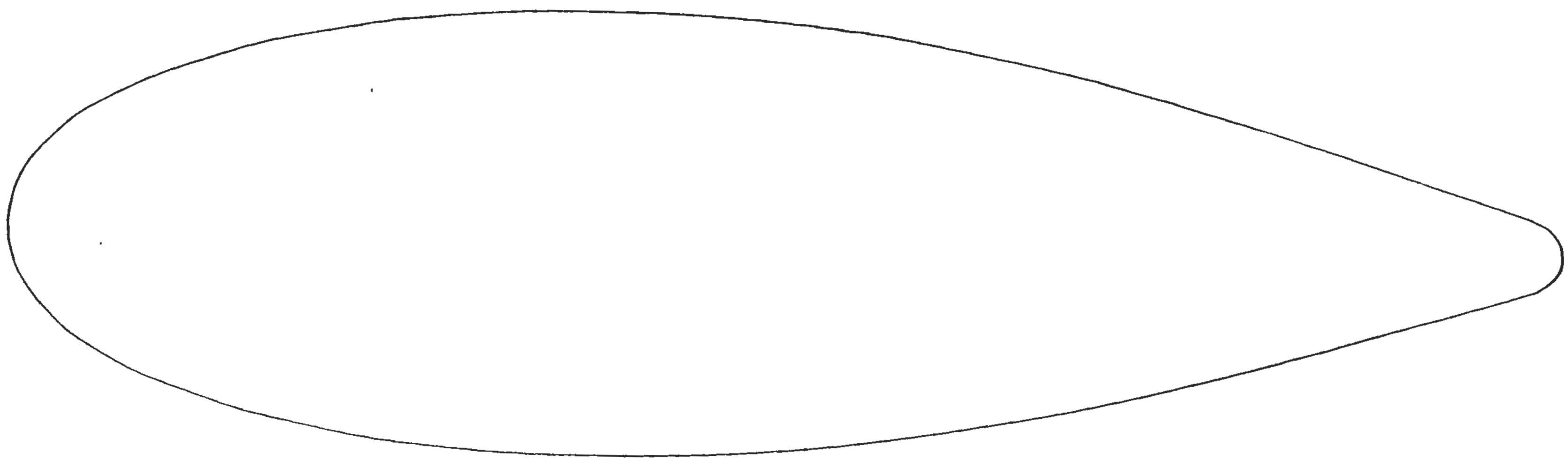
IN/OUT TOLERANCE .0001

DIAGRAM 1.3



CLOSE-UP OF STRAIGHT PORTION

DIAGRAM 1.4



FINAL TOOLPATH

DIAGRAM 1.5

ATTACHMENT (1), PAGE 1

N.C PROCESSOR PROGRAM

```
NL.40LIBR.EXEC.&BCD.NC

<ECHO>
*         USE THIS PROGRAM TO GENERATE AN NCTOOLPATH
*                         ON THE
*               PRATT & WHITNEY TAPE-O-MATIC
*
*FOR MILLING OTHER THAN BASIC VERTICAL AND HORIZONTAL CUTS:
* 1. CREATE NEW GEOMETRY OFFSET BY RADIUS OF CUTTER.
*    A. CUTTER RADIUS INFLUENCED BY LIMITATIONS OF CONTOUR ITSELF,
*       (I.E. DIAMETER OF GEOMETRY, WIDTH OF SLOT, ETC.)
*       DESIRED FINISH (BIGGER THE CUTTER, SMOOTHER THE FINISH),
*       THICKNESS OF PART, HARDNESS OF MATERIAL.
* 2. COPY PART TO NEW NAME.  CALL UP NEW PART.
* 3. #N#MEASURE LENGTH: DIG THE OFFSET GEOMETRY.
* 4. #N#SHOW (LEN)/ .03<CR> (=NUMBER OF POINTS)
*    A. A DISTANCE OF .03 BETWEEN POINTS WITH A .5 INCH END MILL.
*       END MILL PRODUCES 33 COORDINATES PER RUNNING INCH.
*       THE CLOSER THE COORDINATES ARE, THE FINER THE FINISH, AND ALSO THE
*       LONGER IT WILL TAKE TO GENERATE THE POINTS AND THE LONGER THE TAPE
*       WILL BE.
* 5. #N#GEN POI ON N (NUMBER OF POINTS): DIG THE OFFSET GEOMETRY.
* 6. #N#INS POI: XOYOZO BETWEEN EACH OPERATION.
* 7. DELETE EVERYTHING EXCEPT THE TOOLPATH POINTS YOU GENERATED, OR CONSTRUCT
*    A NEW PART FROM JUST THE TOOLPATH POINTS, AND CALL UP THE NEW PART.
*    CHECK, PACK AND FILE THE DATABASE.
* 8. COPY THE TOOLPATH PART TO THE HOST, AND USING THE HOST TERMINAL, CALL UP
*    THE PART AND RUN THE FOLLOWING PROGRAM. (MAY ALSO BE RUN IN BATCH IF
*    DESIRED, BUT IT IS SLOWER.)  FOR A PART WITH 900 POINTS, THIS PROGRAM
*    WILL TAKE ABOUT 4 HOURS.
BEGIN VARPRO2
     CLEAR
     DECLARE TEXTSTRING &CLR,&T
     DECLARE LOCATION &L
     DECLARE ENTITY &E
     DECLARE NUMERAL &I,&X,&Y
     *CLEARS LEAR SIEGLER DISPLAYS
*LET &CLR=CHR($1A$X)
     *CLEARS INSTAVIEWS
LET &CLR=CHR($200C$X)
     SHOW &CLR <ECHO>
  *     PLEASE DO NOT DISTURB THIS TERMINAL        *
  *     PROGRAM IN EFFECT TO CREATE NC TAPE        *<ECHO>
      *EDIT THE NAME OF THIS OUTPUT FILE TO SUIT
OPEN WRITE &OUT 412.RRC.X-Y.COORD
```

```
      *&I COUNTS THE TOOLPATH SEQUENCE NUMBERS
      LET &I=1
      *&E HOLDS THE ENTITY COUNTER, THE FIRSTENT IS THE PPE ENT
      LET &E=FIRSTENT
      *&T IS THE ASCII TAB (FOR TAB SEQUENTIAL MACHINES)
      LET &T=CHR(137)
      * ! MEANS REWIND STOP.
      WRITE &OUT (A1) "!"
      WRITE &OUT (A1) " "
      WRITE &OUT (A1) "!"
WRITE &OUT (I3,A1,F7.4,A1,F7.4,A1,A1,A1) 999, &T,000,&T,&T,"E"
*EDIT THE REPEAT CONTROL TO THE TOTAL NUMBER OF POINTS.
REPEAT 110
      LET &E=NEXTENT(&E)
      OBTAIN POI 1,&E,&L
      LET &X,&Y=X(&L),Y(&L)
      WRITE &OUT (I3,A1,F7.4,A1,F7.4,A1,A1,A1) &I,&T,&X,&T,&Y,&T,&T,"E"
      LET &I=&I+1
      ENDREPEAT
*COMMENTS GO AFTER LAST TAB, M FUNCTIONS GO AFTER NEXT TO LAST TAB
 WRITE &OUT (I3,A1,F7.4,A1,F7.4,A1,I2,A1,A1) &I,&T,&X,&T,&Y,&T,86,&T,"E"
      CLOSE &OUT
      END VARPRO2
*EXIT PART F
<ECHO>

  *     PROGRAM COMPLETE     *
<^K><^K><^K><^K><^K><^K><^K> *BELL
*LOG
<ECHO>
*
*AFTER PROGRAM EXECUTION EDIT THE OUTPUT TEXTFILE AS FOLLOWS:
*
* 1. CHECK FOR ACCURACY - DO COORDINATES SEQUENCE PROPERLY?
* 2. IF THIS IS AN EXTREMELY LONG MILLING TAPE, YOU MAY WANT TO REMOVE THE
*    DECIMAL POINTS AND SPACES FROM THE ENTIRE FILE.
*    (OPTIONAL)   #S,/./,//<CR>  ;  #S,/ /,//<CR>
* 3. EDIT THE E'S AT THE END OF THE LINE AS REQUIRED TO INCLUDE PERTINENT
     INFORMATION, USING #S COMMAND.  SEE EXAMPLE BELOW.
*                 NL.4121.JHW.NCTAPE.13POINTS
*                 TAPE MADE BY JOHN WIEDENHEFT
*                 CODE 4121, 6-28-83,
*                 CV PARTNO. NL.412.JHW.13POINTS
*                 SET UP PLATE ON TOP OF PLYWOOD
*                 XOYO TO BE 3 INCHES UP AND RIGHT FROM LOWER LEFT CORNER.
*                 MAY BE CLAMPED 2 INCHES IN ALL AROUND.
*                 OPERATION TO BE MILLING WITH .500 INCH END MILL
* 4. DELETE REDUNDANT LINES NEAR END OF FILE.
* 5. EDIT THE LAST LINE (HAS M FUNCTION 86) TO CORRECT SEQUENCE NUMBER.
     (86 MEANS 'MACHINING FINISHED' AND 'REWIND TAPE')
```

```
*
* 6. IF ANOTHER OPERATION FOLLOWS:
*    A. INSERT A NEW LINE BEFORE THE LINE CONTAINING X AND Y VALUES OF 000
*       (CREATED IN STEP 6. ABOVE) TO CONTAIN ONLY AN & (MEANS 'STOP' +
        'TOOL CHANGE') IN COLUMN 1.
*    B. EDIT THE LINE CONTAINING X AND Y VALUES OF  000 SO THAT THE SEQUENCE
*       NUMBER BECOMES 999.  EDIT THE X AND Y VALUES TO A POSITION CONDUCIVE
*       TO TOOL CHANGING (OPTIONAL).
*       EDIT THE E TO DESCRIBE THE NEW OPERATION AND/OR TOOL.  EDIT THE E'S
*       IN SUBSEQUENT COORDINATE LINES IF NECESSARY FOR EXPLANATION.
*    C. INSERT A NEW LINE AFTER LINE 999 CONTAINING ONLY AN ! (MEANS 'REWIND
*       STOP') IN COLUMN 1.
<ECHO>
```

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9 April 1984
Project No. 641Y00
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